【Grant-in-Aid for Transformative Research Areas（B）】

Section IV

Title of Project： Frontiers in brain and life sciences on active information gain in an uncertain environment

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【Purpose of the Research Project】

When the organisms confront an uncertain environment, they utilize their ability to predict the environment and update the prediction by its error. They can even actively move to acquire information which reduces the uncertainty of the prediction. We focus on the brain function specified to acquire information to reduce uncertainty in prediction and clarify its computational processes through interdisciplinary research of theory and experiments. In particular, we will develop a computational to model the real brain functions and apply it to the experimental research on the neural basis of the brain function.

Recent progress of the free energy principle (FEP) provided a framework to unify computational concepts such as "predictive coding" and "active inference." The predictive coding further explains the computational mechanism of the hierarchical networks and the active inference newly constructed a mathematical form to explain how the salient stimuli triggered the process of information acquisition. However, the real brain can cope with a more complex situation. We thus extend the current FEP to derive a new framework (new FEP). Further, we will utilize the new FEP framework to quantitatively characterize the rat and macaque behaviors and examine the underlying neuronal mechanism of the computation.

【Content of the Research Project】

(Predictive Coding) Predictive coding is a theory of brain function in which the brain generates and updates an internal model. The model generates predictions of sensory input, which are constantly compared with an actual sensory input. The prediction errors produced by the comparison are then used to update and revise the internal model. The FEP theory suggests that the cortical hierarchical structure and interareal interaction could be responsible for predictive coding. However, the experimental evidence underlying the predictive coding has not been fully elucidated. Osakada group will use state-of-the-art multiscale analyses by combining imaging and viral genetic engineering to reveal the neuronal basis of predictive coding in the mammalian brain. Further, in collaboration with the theory group, the group will propose a new FEP that extends predictive coding and clarify its neural implementation.

(**Active Inference**) Active inference is a way of understanding saliency in behavior. The salience network (SN) is a large-scale brain network of the primate brain that is primarily composed of the anterior insula (AI) and anterior cingulate cortex (ACC). It detects salient stimuli and behavioral errors through self-awareness by integrating sensory, emotional, and cognitive information. Amemori group will use macaque monkeys, which have a brain structure homologous to humans, to clarify the brain function of the SN. To this end, the group will analyze neuronal activity data obtained by a multi-site recording of the SN and clarify the interareal interactions. They will also show the causal function of the SN-striatal pathway using state-of-the-art neural manipulation techniques.

(A new FEP) In a changing and complex environment, the brain recognizes the external world and makes a decision with limited time and computational resources. It thus bounds rationality and optimality, leading to mental conflict and hesitation. In this project, Honda group will develop a new theory of free energy principle (new FEP theory) that explains recognition and decision-making accompanied by mental conflict. The group will also develop a machine learning method (inverse FEP), which decodes mental conflict from time-series data of animal behavior. By integrating and analyzing the decoded mental conflict and neural activity, we will reveal neural mechanisms controlling mental fluctuation, which has been difficult to tackle experimentally and theoretically.

【Expected Research Achievements and Scientific Significance】

The groups will perform interdisciplinary research to unravel the brain function responding to an uncertain environment. When the prediction is ambiguous, the brain updates its prediction by detecting the error and uncertainty of predictions. The research could lead to a new computational principle of artificial intelligence (AI) based on the uncertainty of its predictions. In addition, it could produce a computational algorithm that acquires information autonomously. By investigating the neural processes involved in the ambiguity and certainty of predictions, we can understand neurological and psychiatric disorders. Furthermore, the immune system, which is required to recognize and attack various external enemies, could have sophisticated information strategies to confront the diversity of the external world. Expanding the computational principle makes it possible to explain various biological and life science phenomena, including embryology and immunology.

【Key Words】

Free energy theory, predictive coding, interareal interaction, multisensory integration, active inference, saliency network, curiosity, risk preference, risk aversion, bounded rationality, inverse reinforcement learning, decision-making

【Term of Project】FY2021-2023

【Budget Allocation】105,000 Thousand Yen

【Homepage Address and Other Contact Information】

https://sites.google.com/view/aimai-brain/